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ABSTRACT

Statistics on both the production of astronomers and the employment opportunities now available and reasonably expected for the near future are examined. Barring the sudden and unexpected restoration of basic science to public favor, there seems to be no way of restoring equilibrium between the demand and the supply in astronomical employment without a sharp curtailment in the rate of production of new Ph.D. 's. The problem will probably not be solved even if the rate of supply is reduced by one or two factors. The committee has recommended a number of steps that might be taken to increase the number of positions available to astronomers, particularly in college teaching and in industry, where astronomers are under-represented as compared with scientists in other branches of physics. The report is intended to be a guide for students preparing to enter graduate school about their chances of finding employment, and also to encourage faculty members to take appropriate steps to broaden and diversify the training of their graduate students. (LBH)

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# EMPLOYMENT PROBLEMS IN ASTRONOMY

report of the
Astronomy Manpower Committee
of the
Committee on Science and Public Policy

HE 006653

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NATIONAL ACADEMY OF SCIENCES
Washington, D. C.

March 1975

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NOTICE: The study reported herein was undertaken under the aegis of the Committee on Science and Public Policy (COSPUP) of the National Academy of Sciences-National Research Council.

Responsibility for all aspects of this report rests with the Astronomy Manpower Committee, to which sincere appreciation is here expressed.

The report has not been submitted for approval to the Academy membership or to the Council but, in accordance with Academy procedures, has been reviewed and approved by the Committee on Science and Public Policy. It is being distributed, following this review, with the approval of the President of the Academy.

Support for this activity has been provided by the National Science Foundation.

Dr. Melvin Calvin
Chairman
Committee on Science and Public Policy
National Academy of Sciences

Dear Dr. Calvin:

I take pleasure in forwarding the report of the Astronomy Manpower Committee formed under the Committee on Science and Public Policy to study the employment problems in astronomy.

The committee carefully examined the statistics on both the production of astronomers and the employment opportunities now available and reasonably expected for the near future. Barring the sudden (and unexpected) restoration of basic science to public favor, there seems to be no way of restoring equilibrium between the demand and the supply in astronomical employment without a sharp curtailment in the rate of production of new Ph.D.'s. The problem will probably not be solved even if the rate of supply is reduced by a factor of two. The committee has recommended a number of steps that might be taken to increase the number of positions available to astronomers, particularly in college teaching and in industry, where astronomers are under-represented as compared with scientists in other branches of physics.

We believe that the committee's report should be widely disseminated as soon as possible as a guide for students preparing to enter graduate school about their chances of finding employment. We hope that it also will encourage faculty members to take appropriate steps to broaden and diversify the training of their graduate students in light of the reality that only a small fraction of new Ph.D.'s can look forward to permanent positions in Ph.D.-granting departments, as they could in the past.

The committee would like to record its indebtedness to one of its members, Dr. B. T. Lynds, for writing the final report, and to Mrs. Carol Gregory of the Kitt Peak National Observatory, for transcribing the minutes of its meetings.

Sincerely yours,

Leo Goldberg, Chairman
Astronomy Manpower Committee

21 February 1975

Dr. Philip Handler
President
National Academy of Sciences

Dear Dr. Handler:

The Committee on Science and Public Policy is gratified to transmit to you with its enthusiastic endorsement this report of the Astronomy Manpower Committee. In our view, there can be no question of the critical importance of the unemployment problem in astronomy, both for astronomy and astronomers and for many related fields and endeavors.

We are indebted to this committee and its chairman, Dr. Leo Goldberg, for this carefully conceived and comprehensive report, in which the discussion of the issues is enlightening and the recommendations obviously have great potential value for all concerned.

Sincerely yours,

Melvin Calvin, Chairman
Committee on Science and Public Policy

24 February 1975

The revelations of astronomy in recent times have caught the imaginations of scientists and laymen alike. These advances have been made by professional astronomers whose observational capabilities have been expanded by increasingly sophisticated equipment while their interpretative capability has been expanded by the ever increasing power of theoretical physics. Understandably, the excitement thus engendered has attracted increasing numbers of young scientists to careers in astronomy. But the number of jobs available to astronomers is determined by a quite different set of circumstances and the growing disparity has become a source of serious concern. To examine this situation, the Committee on Science and Public Policy of the Academy brought into being a Committee on Astronomy Manpower. That committee, under the chairmanship of Dr. Leo Goldberg, reports its findings and recommendations in these pages. It must be painful indeed for a committee devoted to the expansion of the science of astronomy, and to communication of that body of knowledge to students and all others who would listen, to warn fellow astronomers and potential students of astronomy that there must be a marked decrease in the production of young astronomers if supply and demand for their services are to attain a reasonable balance.

To the Astronomy Manpower Committee, and to the Committee on Science and Public Policy, I am pleased, on behalf of the Academy, to express our indebtedness and gratitude.

Philip Handler
President

Washington, D.C.
24 February 1975

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ABSTRACT

The rapid pace of discovery in astronomy during the post-Sputnik years has opened broad new fields of exploration and has attracted many research workers. The number of scientists engaged in astronomical research has been increasing at an annual rate of about 15% and this field of research has had a very large influx of new Ph.D.'s over the past three years; the influx came not only from newly trained astronomers but also from persons trained in other fields of physics.

Astronomers are predominantly employed in universities having Ph.D.-producing departments and are under-represented (relative to other fields of physics) in smaller colleges and in industry. This mode of employment, together with the continuing increase in the number of universities offering Ph.D. programs in astronomy and astrophysics, the migration of scientists from neighboring fields into astronomy, and the stoppage of growth in Federal funding of astronomical research have created a serious problem in the employment of astronomers which will probably worsen progressively over the next decade unless firm steps are promptly taken to bring the population of astronomers closer to an approximate equilibrium between supply and demand. The Committee considered a large number of possible mechanisms for achieving the desired balance, of which the following are particularly recommended:

(1) That each university department that produces Ph.D.'s with specialization in astronomy and astrophysics assist in achieving a reduction in their output of Ph.D.'s.

(2) That some of the teaching responsibilities now handled by graduate students be assumed by regular faculty members.

(3) That all astronomy departments achieve close cooperation in the organization of curricula between physics and astronomy specialization and that they review their graduate curricula and their attitudes toward employment opportunities in the light of the current situation in astronomy. An effort should be made to develop graduate programs

that would make the Ph.D. astronomer more attractive to small colleges and to industry.

(4) That the American Astronomical Society take the lead in a concentrated drive to expand undergraduate programs in astronomy and to seek out and encourage all junior colleges, colleges, and universities not now staffed with an astronomer as a faculty member to introduce astronomy programs into their curricula.

(5) That heads of astronomy departments in all state universities make an effort to suggest to their state legislatures that an astronomy course be incorporated as a science credit for all new and continuing education students and teachers.

(6) That all centers of astronomical research attempt to establish mechanisms whereby collaborative research work can be carried out with astronomers who are employed in more isolated research environments.

(7) That NASA make a careful study of the need for support of data analyses in the astronomy program.

I. IDENTIFICATION OF THE PROBLEM

A. Introduction

In the letter to Dr. Handler transmitting the final report of the Astronomy Survey Committee (1), Dr. Harvey Brooks took note of the remarkable vitality of the field of astronomy and astrophysics. The rapid pace of discovery in the science during the past decade has opened broad new fields of exploration and, in so doing, has provided an excitement and intrinsic scientific importance that is outstanding in the physical sciences. This is reflected by the influx of new, young and very talented research workers who find the cosmos to be the greatest area of true mystery left in the physical world.

The discoveries of such phenomena as X-ray stars, quasars, pulsars, neutron stars, cosmic gas masers, infrared sources, cosmic background radiation, and possible gravitational radiation are attracting a substantial flow of first-ranked physicists into the field, another indication of the intellectual vigor and excitement of astronomy.

The number of scientists engaged in astronomical research has been increasing at an annual rate of about 15% (1). The popularity of the field has caused universities to expand their offerings in astronomy and the number of institutions now awarding Ph.D. degrees with astronomical specializations has more than doubled since 1968 although the federal expenditures (in constant 1961 dollars) for astronomy in universities and colleges during the same time period have been declining steadily (2). Because of the predicted decline in the college age population, Allan M. Cartter (3) and others have projected a declining demand for new college teachers in the next two decades. Thus the scientific excitement of astronomy and astrophysics attracts a large number of young people but their normal base of operations, the universities, cannot provide jobs for them. The astronomical problem is more acute than that experienced in the other physical sciences. This is because the rate of growth of manpower in Astronomy and Astrophysics, by Ph.D.

production and by migration from other fields (well above the average for physics as a whole), is greater than the growth of employment opportunities at the Ph.D.-granting institutions, which is where the majority of astronomers work. It is the serious employment problem in astronomy that is discussed in this report.

B. Current Statistics

Summary - The number of Ph.D.'s employed in astronomy increased by 111% (from 623 to 1313) between the years 1970 and 1973 (Table I). This increase is greater than in any other field of physics. The popularity of the field is also shown by the rise from 9th to 3rd place for astronomy as ranked by the total number of Ph.D.'s working in the various fields of physics. Astronomy has also attracted many young physicists, as evidenced by the fact that 28 percent of Ph.D.'s employed in astronomy received their degrees during 1970 to 1973 (Tables II and III). About twice as many Ph.D.'s have entered regular astronomical employment from other fields as have left it (Tables IV and V). Astronomers are very strongly concentrated in universities which have Ph.D.-producing departments and are underrepresented in employment at other colleges and in industry (Table VI). The number of institutions in the United States awarding Ph.D.'s with specializations in astronomy is increasing (Figure 4) and the number of graduate students in astronomy does not appear to be decreasing (Table VII). During the past academic year, at least 180 astronomy Ph.D.'s were granted and well over 900 graduate students were enrolled in astronomy programs (Table VII). At this current rate of Ph.D. production, the ratio of newly trained astronomers to presently identifiable available positions is estimated to be 4 to 1. The number of graduates suggests that over the next 5 years at least 600 new Ph.D.'s will enter the field yet only 50-100 open positions will be available through retirement and probably no more than 200 altogether.

The American Institute of Physics has traditionally taken inventory of the U.S. physics community; until 1971 the material was collected biennially from the National Science Foundation's National

TABLE I

1970 NSF SURVEY AND 1973 AIP SURVEY OF PHYSICISTS' SPECIALIZATIONS

| | 1970 | | | | 1973 | | | |
|---|---|---|---|---|---|---|---|---|
| Subfield of Employment | Number | % | N(PhD) | % | Number | % | N(PhD) | % |
| Acoustics | 1332 | 4.3 | 426 | 3.0 | 1059 | 3.4 | 442 | 2.3 |
| Atomic & Molecular | 1042 | 3.4 | 625 | 4.4 | 1465 | 4.6 | 1134 | 6.0 |
| Biophysics | | | | | 475 | 1.5 | 362 | 1.9 |
| Chemical | | | | | 516 | 1.6 | 419 | 2.2 |
| Electromagnetism | 1333 | 4.3 | 533 | 3.7 | 576 | 1.8 | 298 | 1.6 |
| Electronics | | | | | 1036 | 3.3 | 497 | 2.6 |
| Elementary Particles | 2108 | 6.8 | 1347 | 9.4 | 1583 | 5.0 | 1238 | 6.6 |
| Engineering | | | | | 1287 | 4.1 | 671 | 3.6 |
| Fluids | 1576 | 5.1 | 1002 | 7.0 | 762 | 2.4 | 500 | 2.7 |
| Geophysics | | | | | 673 | 2.1 | 411 | 2.2 |
| Instrumentation | 2872 | 9.3 | 962 | 6.7 | | | | |
| Mathematics | | | | | 684 | 2.2 | 398 | 2.1 |
| Mechanics & Thermal | 1734 | 5.6 | 853 | 6.0 | 538 | 1.7 | 252 | 1.3 |
| Medical | | | | | 736 | 2.3 | 349 | 1.9 |
| Nuclear | 2359 | 7.4 | 1415 | 9.9 | 2222 | 7.1 | 1583 | 8.4 |
| Optics | 2738 | 9.0 | 986 | 6.9 | 2752 | 8.7 | 1305 | 6.9 |
| Plasma | | | | | 766 | 2.4 | 556 | 3.0 |
| Solid State | 5639 | 18.2 | 3248 | 22.7 | 3915 | 12.4 | 2780 | 14.8 |
| Theoretical | | | | | 1093 | 3.5 | 845 | 4.5 |
| Other | 7168 | 23.1 | 2294 | 16.0 | | | | |
| Educational | | | | | 4294 | 13.6 | 1686 | 9.0 |
| General | | | | | 1881 | 6.0 | 1015 | 5.4 |
| Non-Science | | | | | 1294 | 4.1 | 772 | 4.1 |
| Astronomy | 1074 | 3.5 | 623 | 4.4 | 1906 | 6.0 | 1313 | 7.0 |
| Total with known Subfield of employment | 30,975 | 100% | 14,314 | 100% | 31,513 | 100% | 18,826 | 100% |

Data from Physics Today, October 1971 and Physics Today, April 1974.

Register of Scientific and Technical Personnel and in 1973 the AIP continued a similar survey. The data in Table I were obtained from two reports (4, 5) which analyzed the information collected from questionnaires mailed by the AIP. Although the total number of qualified respondents dropped by about 1% between the two surveys -- from 36,336 in 1970 to 35,800 in 1973, the number of respondees holding Ph.D. degrees increased slightly. Those respondents who reported their primary employment in specialties are included in Table I. A detailed comparison of the growth or decline of a field of specialization is difficult because of the redefinition of the fields from 1970 to 1973, but *the very large increase in astronomy (77 percent) total, or 111 percent for Ph.D.'s is quite striking as is the change in ranking by percent of Ph.D.'s in the fields (astronomy is ranked 9th in 1970; ranked 3rd in 1973).* The samples are estimated to be 80% complete for lower degree holders and between 85% and 90% for those holding doctorates.

Figure 1, based on National Register Data and updated by the 1973 AIP survey, shows the increase in the number of persons employed in astronomy. *A large part of the rapid growth of the field of astronomy may be explained as a result of the interest shown in it by the community of young physicists.* This point is illustrated in Table II, based on data published in the Physics Today article. Astronomy ranks second in having the youngest population -- 28 percent of the total Ph.D.'s working in astronomy received their degrees between 1970 and 1973. Astronomy also ranks second in the total number of "new" Ph.D.'s in research fields. Overall, new Ph.D. physicists comprise 23 percent of employed Ph.D. physicists. Note, however, that the number (358) of new Ph.D.'s employed in astronomy does not account for the total influx of astronomy Ph.D.'s (690) shown in Table I. The remaining 48% influx undoubtedly represents a flow of more mature Ph.D. physicists into the field.

At the request of the Astronomy Mini-Study Committee, Ms. Beverly Porter of the AIP analyzed in more detail the 1973 data on astronomers. The age distributions of Ph.D.'s employed in astronomy and in the general physics community are given in Table III and

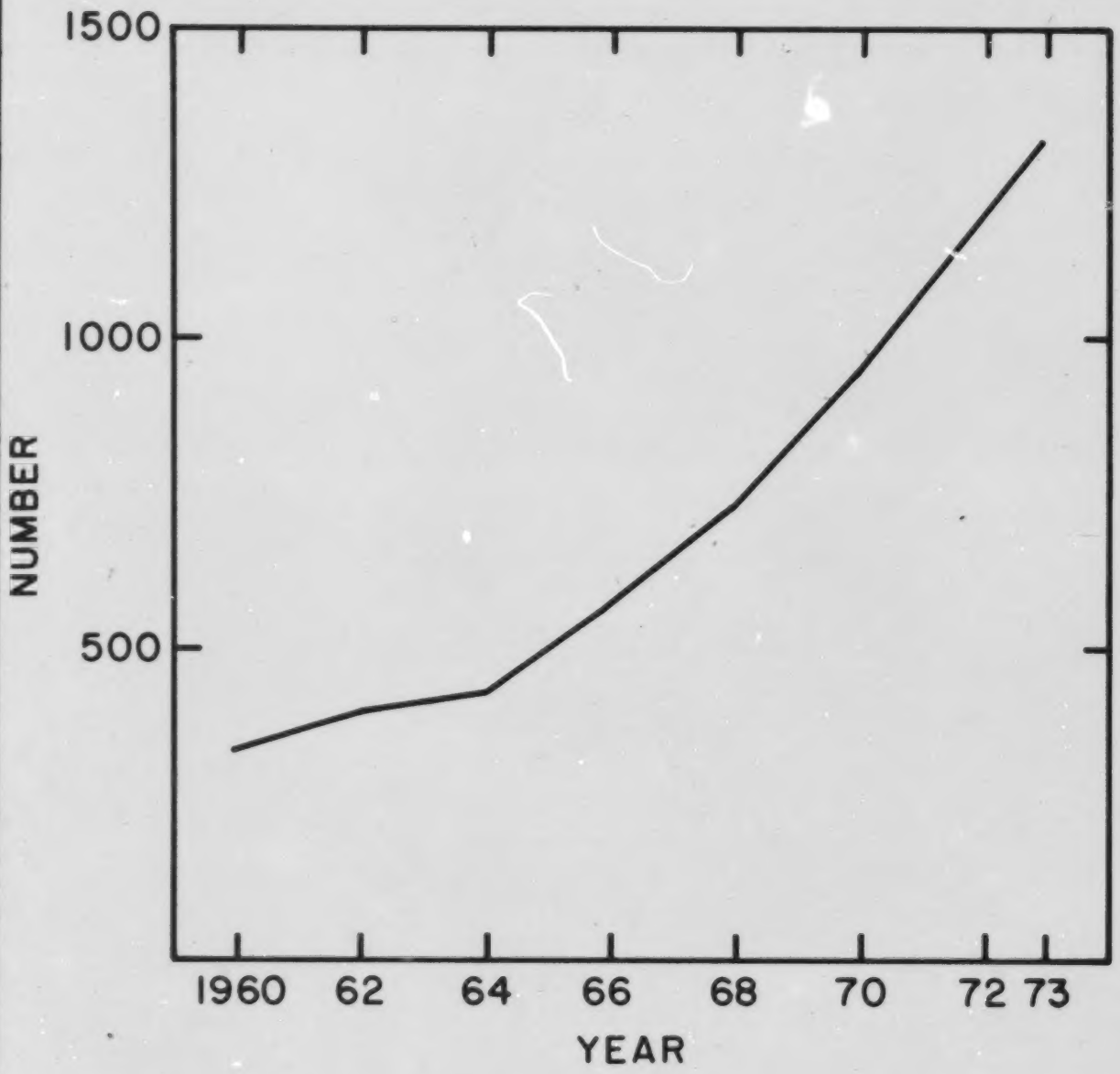


FIGURE 1. Number of Ph.D.'s employed in astronomy

Data from National Register Data and updated by 1973 AIP survey.

TABLE II

NEW PH.D.'s 1970-1973 BY
PHYSICS AND ASTRONOMY SUBFIELDS OF PRESENT WORK*

| | NEW PH.D.'s 1970-1973 | |
|---|---|---|
| SUBFIELD | % of Subfield | Number |
| Medical Physics | 30 | 102 |
| Astronomy | 28 | 358 |
| Geophysics | 28 | 110 |
| Plasma Physics | 28 | 151 |
| Acoustics | 27 | 117 |
| Biophysics | 26 | 90 |
| Elementary Particles | 26 | 308 |
| Educational Physics | 25 | 402 |
| Atomic and Molecular Physics | 24 | 257 |
| Chemical Physics | 24 | 98 |
| Optics | 24 | 304 |
| Electromagnetism | 22 | 63 |
| Physics of Fluids | 22 | 102 |
| Solid State | 22 | 596 |
| General Physics | 20 | 36 |
| Nuclear Physics | 20 | 308 |
| Meteorology | 19 | 29 |
| Mechanics | 18 | 25 |
| Theoretical Physics | 18 | 139 |
| Thermal Physics | 18 | 20 |
| Electronics | 17 | 80 |

*The subfields are ordered from those having the highest proportion of new Ph.D.'s to those having the lowest.

Data from the 1973 AIP Survey.



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TABLE III

AGE DISTRIBUTION OF EMPLOYED PH.D.'s
(Preliminary Data - 96% Complete)

| Age Group | PhD Total No. | % | Astron. PhD No. | % | Age Group | PhD Total No. | % | Astron. PhD No. | % |
|---|---|---|---|---|---|---|---|---|---|
| 20-24 | 7 | 0.0 | 1 | 0.1 | 50-54 | 1493 | 8.3 | 62 | 4.9 |
| 25-29 | 1361 | 7.6 | 154 | 12.2 | 55-59 | 742 | 4.1 | 37 | 2.9 |
| 30-34 | 4929 | 27.4 | 438 | 34.6 | 60-64 | 449 | 2.5 | 22 | 1.7 |
| 35-39 | 3894 | 21.6 | 251 | 19.8 | 65-over | 268 | 1.5 | 27 | 2.1 |
| 40-44 | 2739 | 15.2 | 165 | 13.0 | NR | 60 | | 9 | |
| 45-49 | 2115 | 11.8 | 108 | 8.5 | TOTAL | 18,057 | | 1274 | |

Data from the 1973 AIP Survey.



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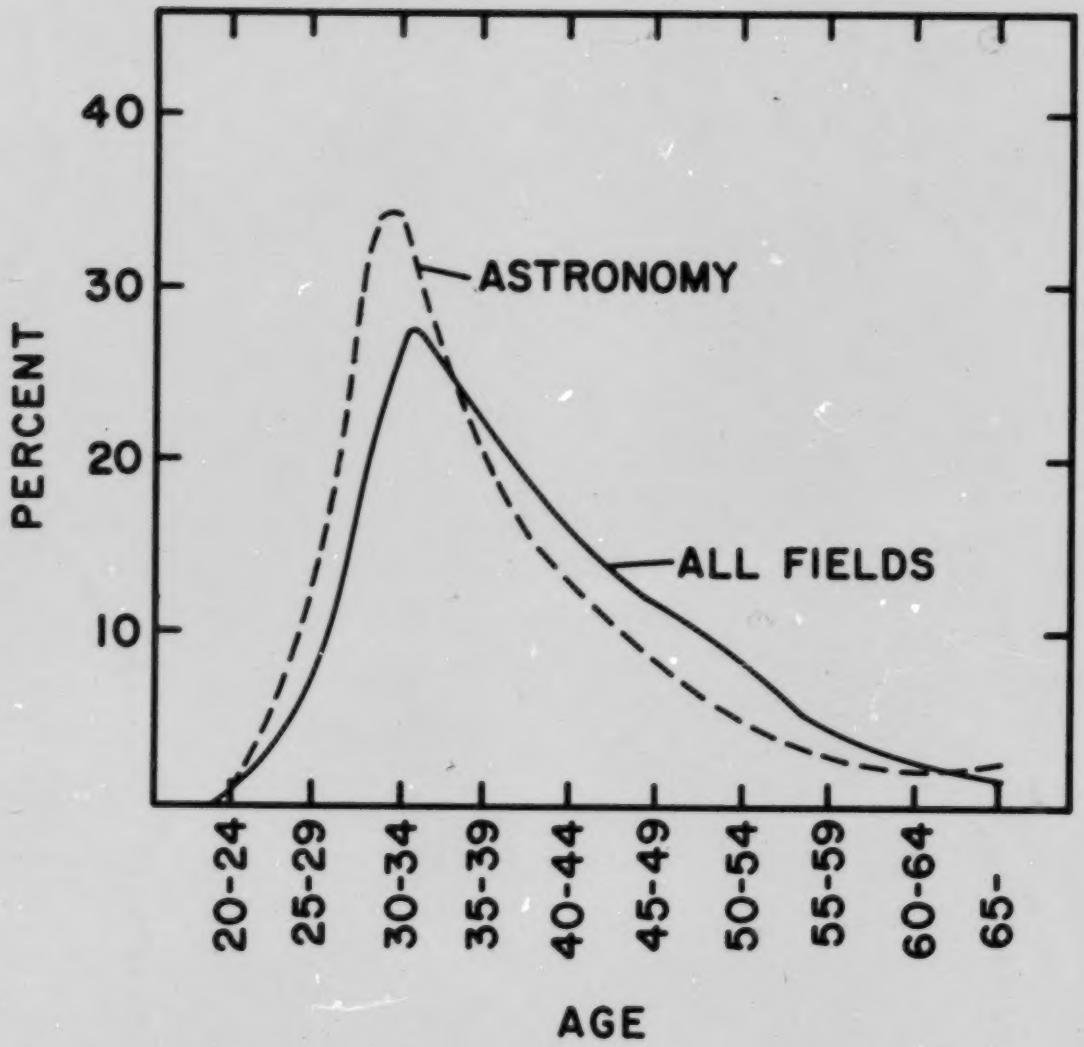


FIGURE 2. Age distribution of employed Ph.D.'s

Data from the 1973 AIP Survey.

Fig. 2. Note the skewness of the age distribution for astronomers. Even if the numbers of young Ph.D.'s entering the field is leveled off in the future, there will remain an enormous imbalance for at least two decades between the numbers of persons retiring per year and those seeking established (tenured) positions.

The AIP uses four modes of identification of a specific field: (1) persons primarily trained in the field, (2) persons primarily trained in the field who are currently working in the field, (3) persons primarily working in the field and (4) persons primarily identifying themselves as specialists in the field. For astronomy, these numbers are:

TABLE IV

TOTAL NUMBER OF ASTRONOMERS
BY DEGREE AND TRAINING

| Astronomers | Ph.D. | Others | Total |
|---|---|---|---|
| Number trained | 1164 | 499† | 1553 |
| Number trained and working | 885 | 254† | 1139 |
| Number working | 1313 | 593 | 1906 |
| Number self-identified | 1442 | 735 | 2177 |

†Masters degree only included

The persons primarily trained in astronomy received advanced degrees in astronomy or in a related field (usually physics) but with an astronomy specialization.

Of the 1164 Ph.D.'s trained in astronomy, 1135 replied to the question on their current field of employment -- 885 are working in astronomy; 60 are working in educational physics and/or astronomy; and 190 moved into other fields of physics. The 1313 Ph.D.'s currently working in the field are made up of the 885 trained in astronomy, 390 not trained in astronomy, and 38 others who reported they were working in the field but did not identify their field of training. Table V illustrates the mobility among the various fields. Clearly, about twice as many Ph.D.'s have entered regular astronomical employment as have left it. This reflects the developments in modern astrophysics and its overlap with areas traditionally in the realm of physics.

TABLE V

MOBILITY BY FIELD OF THE NUMBER ENTERING AND LEAVING ASTRONOMY

(omitting post-doctoral positions)

| Field of Degree | Number leaving for Astronomy | Number entering from Astronomy |
|---|---|---|
| Elementary Particles | 72 | 1 |
| Nuclear Physics | 58 | 2 |
| Atomic & Molecular Physics | 46 | 1 |
| Theoretical Physics | 39 | 3 |
| Optics | 18 | 24 |
| Fluids | 18 | 10 |
| Solid State | 18 | 2 |
| Geophysics | 18 | 14 |
| Electromagnetics | 13 | 9 |
| Plasma | 12 | 8 |
| Other Physics | 23 | 24 |
| Other Science | 21 | 49 |
| Non-Science | - | 33 |
| TOTAL | 356 | 180 |

Optics is the only field that received more Ph.D.'s from astronomy than it has sent to astronomy. The fields that provided the largest proportion of entrants into astronomy are elementary particles, nuclear physics, atomic and molecular physics and theoretical physics; there is essentially no reverse flow. Three of the four fields (all but nuclear physics) also have a high percentage of young people, who are also primarily employed at universities. Of the 171 persons holding post-doctoral appointments in astronomy, 2 did not specify their field of training; 135 were trained in astronomy and 34 moved in from other fields. Ten astronomy-trained persons held post-doctoral appointments in other fields (primarily in geophysics and plasma physics, none in elementary particles).

In Figure 3, the percentage of scientists in a given field under age 35 is plotted against the percentage employed at universities. Those fields having the highest percentage of persons under 35 also have the largest percentage employed at universities. Theoretical Physics (with 49% under 35) has more than 80% of its specialists employed at universities; this field is followed by Elementary Particles (56% under 35, 73% at universities); Biophysics (50% under 35, 71% at universities); Atomic and Molecular Physics (49% under 35, 70% at universities); and Astronomy (55% under 35, 57% at universities). On the average for all physicists, 43.7% are under 35 and 42.1% are employed at universities.

Astronomers are very strongly concentrated in universities which have Ph.D.-producing departments, as shown in Table VI, which contains a detailed analysis prepared by Porter.

TABLE VI

TYPES OF EMPLOYMENT OF PH.D. ASTRONOMERS

| | Astronomy | | Total Physics | |
|---|---|---|---|---|
| | N | % | N | % |
| Univ. with Ph.D.-producing depts. | 647 | 50.8 | 6534 | 36.4 |
| Univ. with M.A.-producing depts. | 30 | 2.4 | 776 | 4.3 |
| Univ. with B.A.-producing depts. | 46 | 3.6 | 1520 | 8.4 |
| Univ. and Colleges -- Other | 28 | 2.2 | 295 | 1.6 |
| Junior Colleges | 5 | 0.4 | 175 | 1.0 |
| Secondary Schools | - | - | 57 | 0.3 |
| Industry | 82 | 6.4 | 4063 | 22.5 |
| Government | 225 | 17.7 | 1935 | 10.7 |
| Non-profit Organizations | 42 | 3.3 | 450 | 2.5 |
| Federally Funded R&D Centers | 157 | 12.3 | 2166 | 12.0 |
| Other | 11 | 0.9 | 66 | 0.4 |
| Unknown | 1 | - | 20 | - |
| TOTAL | 1274 | 100% | 18057 | 100% |

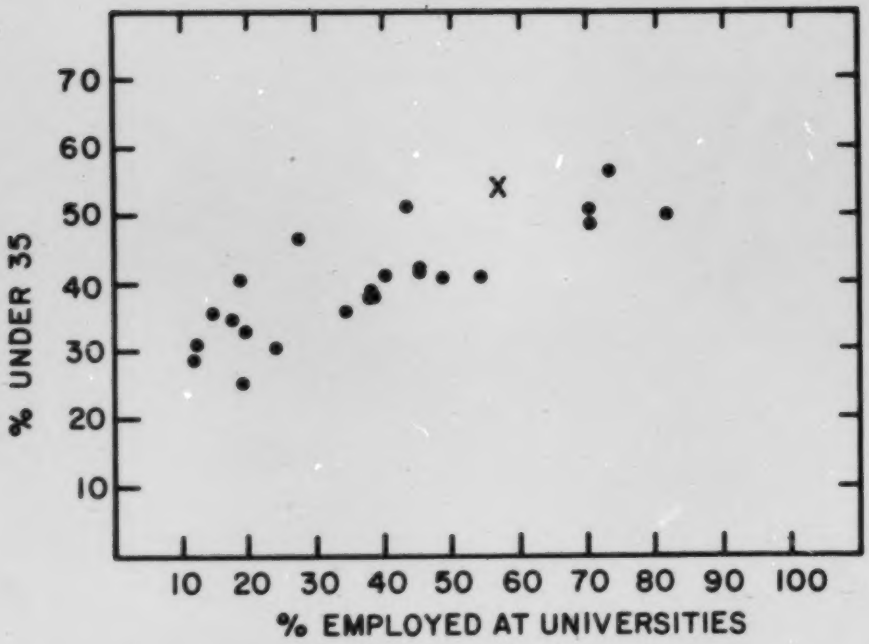


FIGURE 3. Percentage of scientists under age 35 vs. percentage employed at universities for various fields of specialization. The cross represents astronomy.

Based on data from Physics Today, April 1974.

Porter emphasizes that *the major difference between Ph.D.'s working in astronomy and those working in other fields is the high concentration of the astronomy Ph.D.'s in the university Ph.D. producing departments and in government, and their low representation in industry.*

The number of institutions in the United States awarding Ph.D.'s with specializations in astronomy has been steadily increasing since 1960. Figure 4 is taken from the Astronomy Survey Committee report (6) and includes an extrapolation to 1971-73, shown by the dotted line.

A special report (7) by the President of the AAS and the Chairman of the AAS Committee on Manpower and Employment (Bok and Goldsmith, respectively) contains the data listed in Table VII, which is reported to be almost a complete survey of Ph.D.-granting astronomy departments but a very incomplete sample of physics departments which allow specialization in astronomy. (The extrapolated number of 69 universities in Figure 4 is from this survey.)

The 69 universities in the survey reported a total astronomy graduate enrollment of 939. The AIP publication Physics Manpower 1973 lists a comparable total physics graduate student enrollment of 10,227. The projected number of doctorates to be granted in physics in 1973-74 is 1300; Table VII projects a production of about 180 in astronomy. Astronomers now represent 7% of the employed physicists, 9% of the enrolled physics students and 14% of the projected 73-74 Ph.D. recipients. The general trend is quite clear; *the declining number of doctorates granted in physics is established while the number of doctorates granted in astronomy is continuing to increase. Furthermore, a significant fraction of the new Ph.D.'s in certain other fields of physics is migrating into astronomy.*

Bok and Goldsmith (7) summarize that over the period from October 1972 -- June 1974, "The total number of positions in astronomy departments, 586, is estimated to increase by at most 21 by June 1974. If we add in an estimate of 30 positions which may open through retirement, we find that astronomy departments might provide 50 openings for the expected 290 Ph.D.'s to be produced by the same departments,

plus whatever Ph.D.'s from physics and related fields may compete for these openings. Thus it appears that more than 80% of the new Ph.D.'s will not join the Ph.D.-granting departments." This conclusion is particularly serious when one considers the fact that more than half (cf. Table VI) of the Ph.D. astronomers are employed in the Ph.D.-granting departments of universities. The departments of these institutions are heavily populated with non-faculty astronomy positions such as post-doctoral appointees.

A recent survey of 12 of the leading astronomy departments indicates that 81% of the faculties of these departments hold tenured positions (range is from 47% to 100%). Therefore it appears that those astronomers holding non-faculty positions at these universities as well as the new Ph.D.'s now being produced will not be able to find employment in the traditional manner.

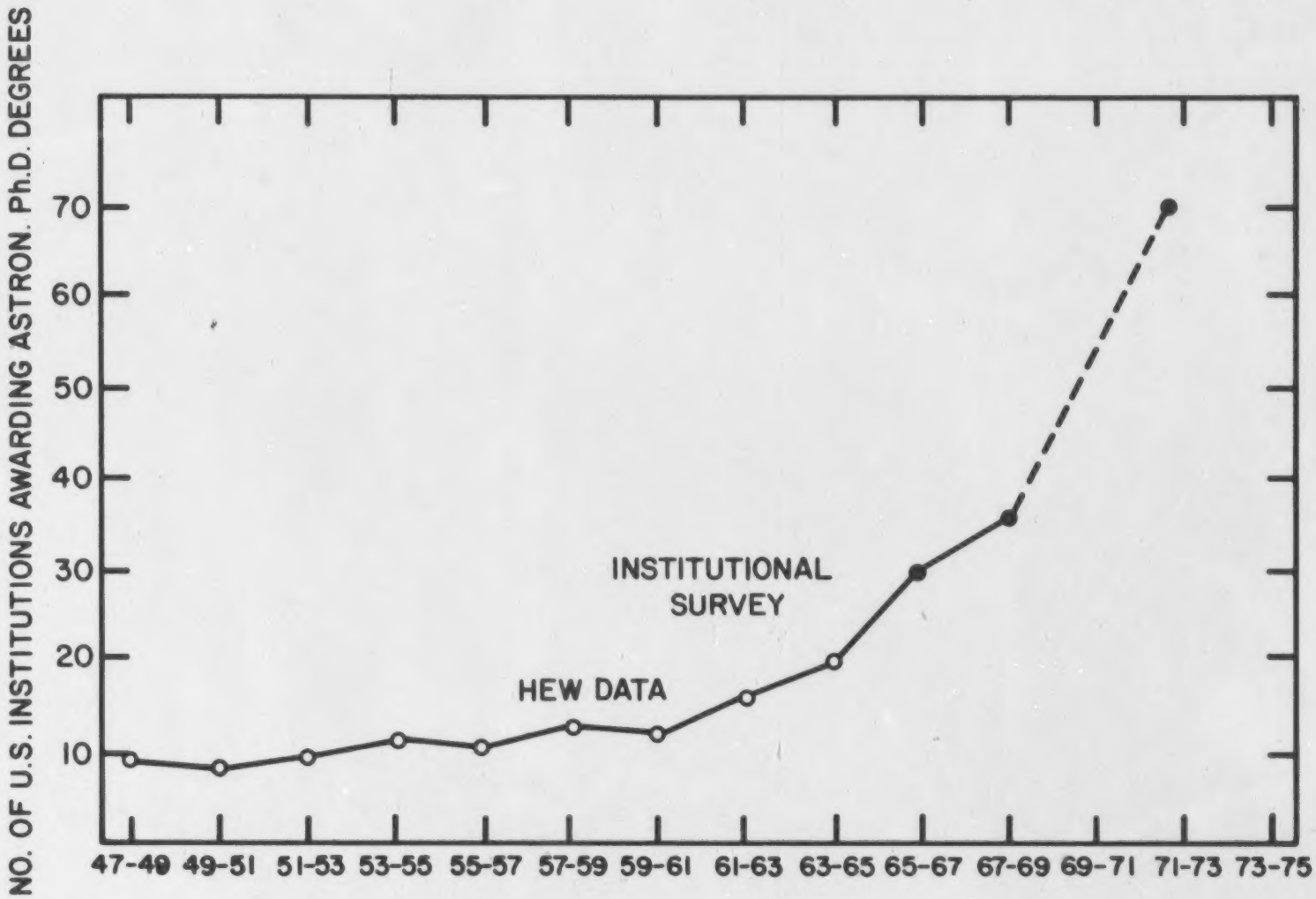


FIGURE 4. Number of U.S. institutions awarding astronomy Ph.D. degrees as a function of time (the dotted line is an extrapolation).

Data from Astron. and Astrophys. for the 1970's, Vol. 2 with extrapolation.

TABLE VII

RESULTS OF A SURVEY OF ASTRONOMY AND PHYSICS DEPARTMENTS CONCERNING RECENT PH.D. PRODUCTION AND DIFFICULTIES WITH EMPLOYMENT

(from Bok and Goldsmith)

| | 44 Astronomy Depts. | 25 Physics Depts. |
|---|---|---|
| (1) Ph.D.'s granted in astronomy Sept. 1969-Sept. 1972 | 361 | 19 |
| (2) Estimated Ph.D. production | | |
| Oct. 1972-June 1973 | 133 | 15 |
| July 1973-June 1974 | 157 | 23 |
| (3) Number of full-time faculty positions in astronomy | 392 | 59 |
| (4) Nonfaculty astronomy positions | 194 | 21 |
| (5) Estimated change in (3) and (4) by June 1974: | | |
| Faculty positions | + 12 | + 4 |
| Nonfaculty positions | + 9 | + 2 |
| (6) Number of former Ph.D. students who are known to have serious difficulty in finding full-time employment in astronomy | 18 | 3 |
| (7) Number of research associates and post-doctoral fellows who are having serious difficulty securing full-time employment in astronomy | 19 | 10 |
| (8) Number of astronomy graduate students now enrolled | 839 | 100 |

Data from Bok and Goldsmith special report in Mercury, July,Aug. 1973.

C. Research Funding

Table VIII contains the estimated expenditures for basic research in universities and colleges (in current dollars and in 1961 dollars) together with the percentage of these funds which are derived from federal sources (2).

Table VIII clearly indicates how heavily the fields of physics and astronomy depend on federal support. In both fields the university federal support has been declining as illustrated in Table IX, based on the same data source of Table VIII.

The federal obligations for basic research by supporting agency are shown in Table X [from (2)].

Other federal funds for astronomical research outside of direct university support are available. Table XI (#1, Vol. 2) identifies the federal agencies which contribute to the support of astronomical research including the costs of operating the National Observatories, Sacramento Peak Observatory, Naval Observatory, etc.

Several conclusions can be drawn from Table XI: (1) the number of federal agencies supporting astronomy is decreasing such that in 1972 95% of the federal funds for astronomy are derived from NASA and the NSF (82% of ground-based support); (2) the amount of federal funds for astronomy is decreasing even when measured in current dollars; and (3) more than 70% of the funds allocated to astronomy are dedicated to the space program. During the past decade the NASA astronomy programs have included an Apollo experiment, space flight operations (including Skylab ATM experiment), Orbiting Solar Observatories, Orbiting Astronomical Observatories, Orbiting Geophysical Observatories, Explorers, Sounding Rockets, Pioneers, and Viking missions.

Table XII contains NASA's estimated budget for "basic" research in astronomy for FY73-78.

The distribution of NSF funds for astronomy is shown in Table XIII, which is based on information published in NSF Annual Reports.

The allocation of NSF funds for astronomy is also illustrated in Figures 5 and 6. The beginnings of several major astronomical programs

are identified in Figure 5, which expresses the funds as a percentage of the total NSF budget. Figure 6(A) illustrates the fact that the support of science research projects for all fields has increased over the years, and Figure 6(B) contains a breakdown of how the research project support funds have been allocated by scientific fields.

TABLE VIII

TOTAL EXPENDITURES FOR BASIC RESEARCH AT UNIVERSITIES AND COLLEGES AND PERCENTAGE OF FEDERAL CONTRIBUTIONS TO THIS EXPENDITURE

| | 1964 | | | 1966 | | | 1968 | | | 1970 | | | 1972 (est.) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Current $ M | 1961 $ M | % Fed. | Current $ M | 1961 $ M | % Fed. | Current $ M | 1961 $ M | % Fed. | Current $ M | 1961 $ M | % Fed. | Current $ M | 1961 $ M | % Fed. |
| TOTAL | 1,261 | 1,159 | 61 | 1,601 | 1,378 | 63 | 2,011 | 1,584 | 62 | 2,186 | 1,555 | 59 | 2,541 | 1,626 | 55 |
| ENGINEERING | 162 | 149 | 65 | 226 | 194 | 67 | 270 | 212 | 67 | 280 | 199 | 65 | 309 | 198 | 63 |
| PHYSICAL SCIENCES | 212 | 195 | 77 | 270 | 233 | 77 | 296 | 233 | 75 | 300 | 213 | 79 | 329 | 210 | 71 |
| Astronomy | 15 | 14 | 87 | 20 | 17 | 85 | 22 | 18 | 82 | 16 | 11 | 88 | 22 | 14 | 68 |
| Chemistry | 72 | 67 | 69 | 82 | 71 | 73 | 96 | 76 | 73 | 97 | 69 | 69 | 112 | 72 | 65 |
| Physics | 111 | 102 | 86 | 151 | 130 | 81 | 160 | 126 | 83 | 156 | 111 | 85 | 163 | 104 | 76 |
| Others | 13 | 12 | 46 | 17 | 15 | 59 | 17 | 14 | 76 | 31 | 22 | 68 | 32 | 20 | 66 |
| ENVIRONMENTAL SCIENCES | 52 | 48 | 75 | 62 | 53 | 76 | 109 | 86 | 65 | 105 | 75 | 69 | 138 | 88 | 69 |
| MATHEMATICAL AND COMPUTER SCIENCES | 39 | 36 | 54 | 48 | 41 | 54 | 63 | 50 | 54 | 82 | 58 | 52 | 79 | 51 | 52 |
| LIFE SCIENCES | 643 | 591 | 58 | 784 | 675 | 60 | 940 | 740 | 62 | 1,058 | 754 | 56 | 1,228 | 786 | 53 |
| Biological Sciences | 287 | 264 | 44 | 367 | 316 | 44 | 433 | 341 | 47 | 450 | 320 | 44 | 580 | 371 | 42 |
| Clinical Med. | 311 | 286 | 70 | 360 | 310 | 78 | 443 | 349 | 78 | 497 | 354 | 70 | 571 | 365 | 65 |
| Others | 45 | 41 | 60 | 58 | 49 | 57 | 64 | 50 | 55 | 111 | 78 | 39 | 77 | 49 | 42 |
| PSYCHOLOGY | 36 | 33 | 67 | 44 | 38 | 68 | 62 | 49 | 63 | 64 | 46 | 63 | 88 | 56 | 59 |
| SOCIAL SCIENCES | 98 | 90 | 38 | 131 | 112 | 40 | 195 | 154 | 42 | 217 | 154 | 38 | 275 | 176 | 33 |
| OTHER SCIENCES | 18 | 17 | 28 | 36 | 31 | 58 | 77 | 61 | 48 | 80 | 57 | 51 | 95 | 61 | 56 |

Data from Science Indicators 1972.

TABLE IX

DISTRIBUTION OF FEDERAL FUNDS FOR UNIVERSITY BASIC RESEARCH
(Percent of Total)

| FIELD | 1964 | 1966 | 1968 | 1970 | 1972 (est.) |
|---|---|---|---|---|---|
| ENGINEERING | 13.7 | 15.0 | 14.5 | 14.1 | 16.2 |
| PHYSICAL SCIENCES | 21.4 | 20.7 | 18.6 | 18.4 | 16.6 |
| Astronomy | 1.7 | 1.7 | 1.4 | 1.1 | 1.1 |
| Chemistry | 6.5 | 5.9 | 5.6 | 5.5 | 5.2 |
| Physics | 12.4 | 12.1 | 10.6 | 10.2 | 8.8 |
| Others | 0.8 | 1.0 | 1.0 | 1.6 | 1.5 |
| ENVIRONMENTAL SCIENCES | 5.1 | 4.7 | 5.7 | 5.6 | 6.7 |
| MATHEMATICAL AND COMPUTER SCIENCES | 2.7 | 2.6 | 2.7 | 3.3 | 2.9 |
| LIFE SCIENCES | 48.4 | 46.8 | 46.7 | 45.8 | 46.1 |
| PSYCHOLOGY | 3.1 | 3.0 | 3.1 | 3.1 | 3.7 |
| SOCIAL SCIENCES | 4.8 | 5.3 | 6.6 | 6.4 | 6.4 |
| OTHERS | 0.7 | 2.1 | 3.0 | 3.2 | 3.8 |

Data from Science Indicators 1972.

TABLE X

FEDERAL OBLIGATIONS FOR BASIC RESEARCH, BY SUPPORTING AGENCY

| AGENCY | 1964 Current $ M | 1964 % | 1966 Current $ M | 1966 % | 1968 Current $ M | 1968 % | 1970 Current $ M | 1970 % | 1972 Current $ M | 1972 % |
|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL | 1567 | | 1844 | | 2072 | | 2062 | | 2411 | |
| DEP'T. AGRICULTURE | 68 | 4.3 | 94 | 5.1 | 100 | 4.8 | 116 | 5.6 | Included in 'Others' | |
| DOD | 241 | 15.4 | 262 | 14.2 | 263 | 12.7 | 247 | 12.0 | 270 | 11.2 |
| HEW | 274 | 17.5 | 326 | 17.7 | 397 | 19.2 | 388 | 18.8 | 461 | 19.1 |
| AEC | 238 | 15.2 | 281 | 15.2 | 282 | 13.6 | 287 | 13.9 | 268 | 11.1 |
| NASA | 524 | 33.4 | 559 | 30.3 | 656 | 31.7 | 637 | 30.9 | 768 | 31.9 |
| NSF | 155 | 9.9 | 223 | 12.1 | 252 | 12.2 | 245 | 11.9 | 368 | 15.3 |
| OTHERS | 66 | 4.2 | 98 | 5.3 | 122 | 5.9 | 142 | 6.7 | 275 | 11.4 |

Data from Science Indicators 1972.

*TABLE XI*

*TOTAL FEDERAL FUNDING FOR ASTRONOMICAL RESEARCH*

| | 1966 $ M | 1968 $ M | 1970 $ M | 1972 $ M |
|---|---|---|---|---|
| *GROUND-BASED ASTRONOMY* | | | | |
| *NSF* | 22.9 | 30.4 | 23.3 | 29.9 |
| *NASA* | 9.4 | 10.0 | 9.0 | 9.0 |
| *AIR FORCE* | 9.6 | 8.5 | 7.3 | 2.0 |
| *NAVY* | 8.7 | 8.2 | 6.7 | 5.0 |
| *ARPA* | 2.6 | 2.7 | 1.3 | -0- |
| *SAO* | 1.5 | 1.5 | 1.5 | 1.5 |
| *SUB-TOTAL* | 54.7 | 61.3 | 49.1 | 47.4 |
| *SPACE PROGRAM ASTRONOMY* | | | | |
| *NASA* | 134.5 | 166.0 | 161.4 | 139.4 |
| *TOTAL* | 189.2 | 227.3 | 210.5 | 186.8 |

TABLE XII

NASA ESTIMATED BUDGET FOR "BASIC"
RESEARCH IN ASTRONOMY

($ in Millions)

| | FY1973 | FY1974 | FY1975 | FY1976 | FY1977 | FY1978 |
|---|---|---|---|---|---|---|
| LUNAR AND PLANETARY PROGRAM | | | | | | |
| SR&T Advanced Studies | 2.6 | 2.1 | 3.0 | 3.1 | 2.8 | 2.8 |
| Data Analysis | - | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 |
| Planetary Astronomy | 4.8 | 3.8 | 4.2 | 4.2 | 4.2 | 4.2 |
| Pioneer | 5.1 | 2.9 | 2.6 | 2.0 | 1.8 | 1.8 |
| Viking | 5.3 | 5.0 | 2.8 | 0.8 | 0.7 | - |
| Helios | 1.0 | 0.6 | 0.7 | 0.6 | - | - |
| Lunar Science Operations | 1.0 | 0.2 | 0.5 | 0.5 | 0.5 | 0.4 |
| Mariner Jupiter/Saturn | - | 2.7 | 7.0 | 8.2 | 5.2 | 2.1 |
| SUBTOTAL L&P: | 19.8 | 17.7 | 21.2 | 19.9 | 16.8 | 12.9 |

The budgets include only approved and continuing programs and not new starts that may be approved in the future. Possible candidates for new starts that may have an impact on the employment situation in astronomy are the subject of a recently published study by the Space Science Board of the National Academy of Sciences-National Research Council (opportunities and choices in Space Sciences, 1974).

Data from NASA Headquarters

TABLE XII (con't.)

| Physics & Astronomy Programs | FY1973 | FY1974 | FY1975 | FY1976 | FY1977 | FY1978 | FY1979 |
|---|---|---|---|---|---|---|---|
| OAO | 5.7 | 2.3 | 2.5 | 2.8 | 1.1 | 0.3 | - |
| OSO | 20.4 | 12.8 | 5.4 | 2.6 | 0.6 | - | - |
| HEAO | 14.2 | 3.2 | 30.2 | 42.5 | 26.8 | 15.2 | 8.1 |
| SMM (Phase B) | - | - | 1.5 | 1.0 | - | - | - |
| LST (Phase B) | - | - | 3.0 | 5.0 | - | - | - |
| Explorers | 9.5 | 13.5 | 14.7 | 9.5 | 16.5 | 16.5 | 16.5 |
| Sounding Rockets | 10.9 | 11.6 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| Airborne Research | 2.3 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Balloon Program | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| Spacelab Payloads | - | 0.3 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Data Analysis | 1.2 | 1.3 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 |
| Skylab Data Analysis | - | - | 1.4 | 6.0 | 4.6 | - | - |
| SR&T | 7.7 | 8.0 | 8.5 | 8.5 | 8.5 | 8.5 | 8.5 |
| SUBTOTAL P&A: | 72.6 | 56.2 | 86.1 | 96.8 | 77.0 | 59.4 | 52.0 |
| SUBTOTAL L&P: | 19.8 | 17.7 | 21.2 | 19.9 | 16.8 | 12.9 | |
| TOTAL | 92.4 | 73.9 | 107.3 | 107.7 | 93.8 | 72.3 | 52.0 |

*TABLE XIII*

*DISTRIBUTION OF NSF FUNDS FOR ASTRONOMY*

*(Current $M)*

| | 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 |
|---|---|---|---|---|---|---|---|
| TOTAL NSF FUNDS | 495 | 400 | 438 | 511 | 619 | 639 | 663 |
| UNIVERSITY GRANTS PROGRAM | | | | | | | |
| Astronomy | 6.2 | 5.9 | 5.8 | 6.4 | 7.8 | 8.8 | 9.6 |
| Physics* | 0.7 | 0.7 | 0.9 | 0.7 | 1.3 | 1.3† | 1.9† |
| Chemistry & Math* | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| KPNO | 12.5 | 5.7 | 5.8 | 7.2 | 7.7 | 7.8 | 7.8 |
| NRAO | 4.9 | 7.3 | 6.4 | 6.8 | 6.7 | 10.0 | 12.1 |
| CTIO | 2.3 | 4.5 | 1.9 | 2.3 | 2.5 | 2.7 | 2.6 |
| HAO* | 1.3 | 1.3 | 1.4 | 1.5 | 1.5 | 1.6 | 1.6 |
| NAIC* | - | 0.6 | 1.1 | 4.0 | 3.1 | 2.1 | 2.1 |
| UNIV. ASTRONOMY RESEARCH INSTITUTIONS | 0.7 | 0.3 | 0.2 | 0.3 | 0.3 | - | - |
| SCIENCE DEVELOPMENT GRANTS | 2.4 | 2.1 | 0.6: | 0.6: | - | - | - |
| TOTAL ASTRONOMY | 31.1 | 28.5 | 24.2 | 29.9 | 31.0 | 34.4 | 37.8 |
| % OF TOTAL NSF FUNDS | 6.3 | 7.1 | 5.5 | 5.9 | 5.0 | 5.4 | 5.7 |

* *Estimates of astronomy funds included in a larger total.*

† *Information provided by NSF Physics Grants Program.*

Data from NSF Annual Reports.

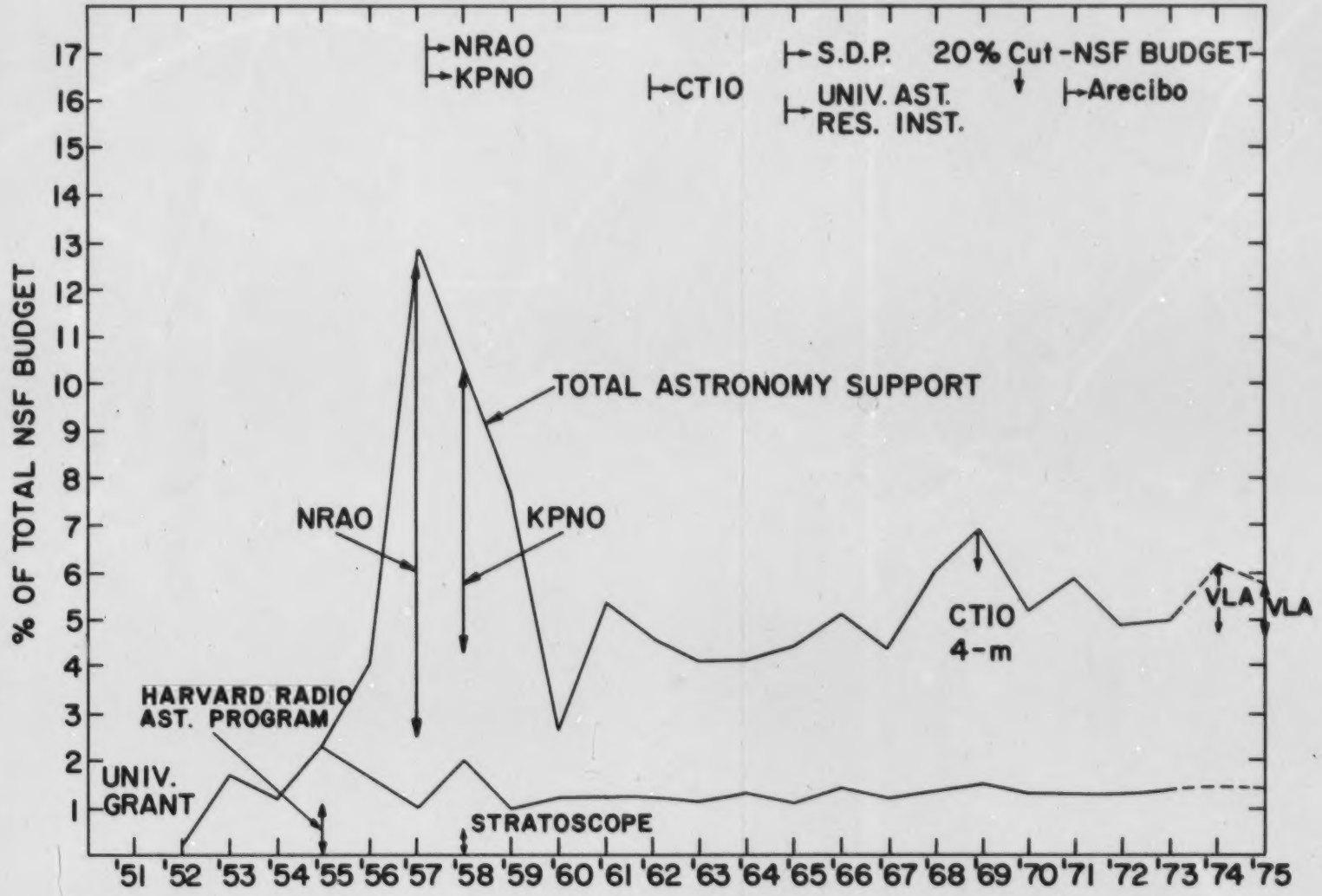


FIGURE 5. NSF funding for astronomy

Data from NSF Annual Reports.

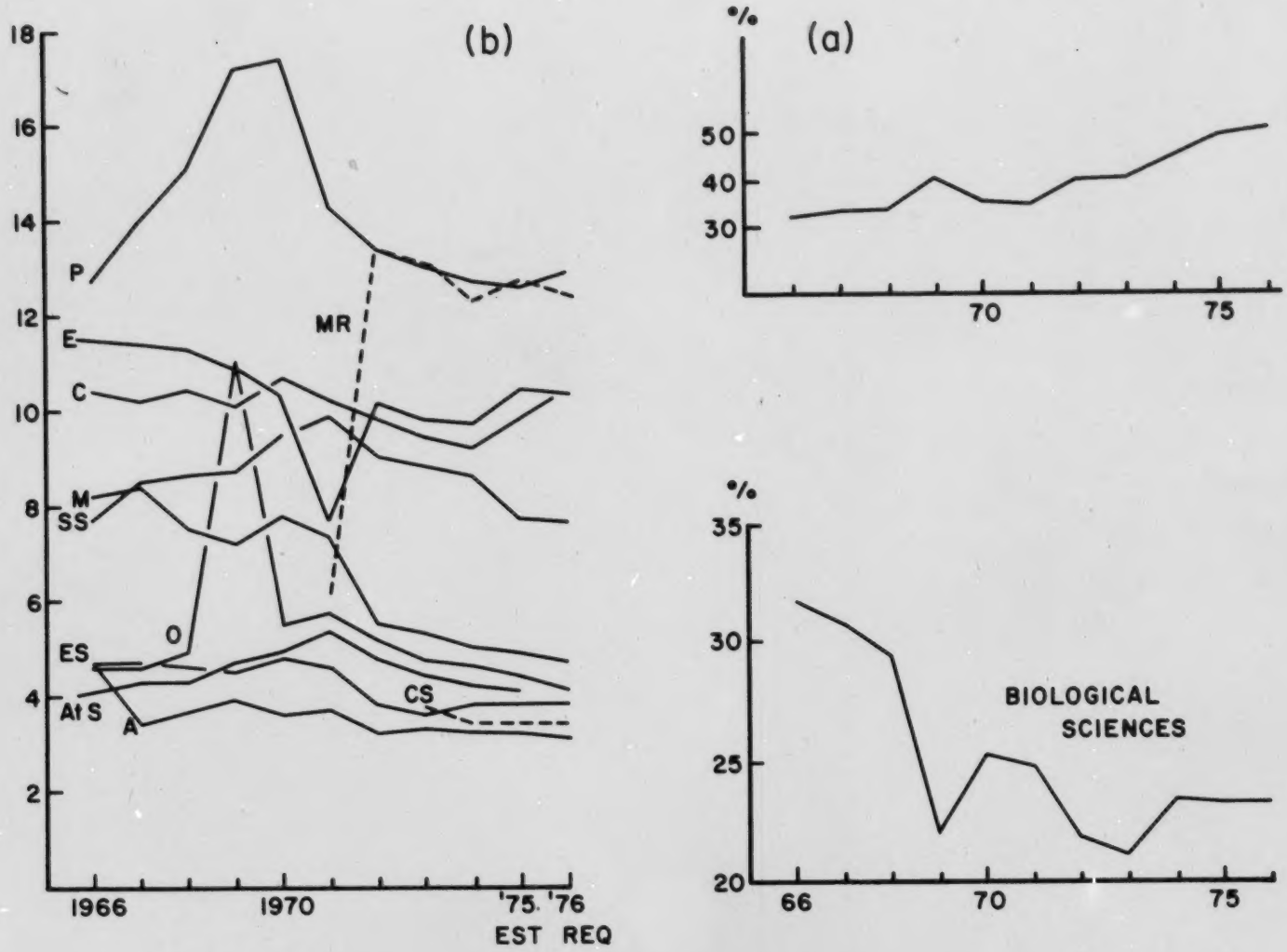


FIGURE 6 (A). Percent of NSF funds for Scientific Research Project Support.

(B). Percent of Project Support Funds for the various fields of research. The fields are identified as follows: Physics (P), Engineering (E), Materials Research (MR), Chemistry (C), Social Sciences (SS), Mathematics (M), Oceanography (O), Atmospheric Sciences (At S), Earth Sciences (ES), Computer Sciences (CS), and Astronomy (A).

Data from NSF Annual Reports and NSF News Release 75-9 dated Feb. 3, 1975.

D. Identification of Specific Issues

The statistics cited in the previous section clearly indicate that there will be a serious employment problem among Ph.D. astronomers in the immediate future. The 800 graduate students now in training indicate a production of about 150 new Ph.D.'s per year. The number of available jobs per year in universities is about 30. Unless some modifications are made to change the trends there will be an even greater employment crisis in the long-range future of the science. The one basic question to be addressed is: How can the population of astronomers be brought into an approximate equilibrium between (1) supply and (2) demand? We must consider how to decrease (1) and increase (2).

In order to assess the situation realistically, one must review the financial support for astronomy, study the graduate training procedures (both quantitatively and qualitatively), and search for a wider diversification in employment opportunities for astronomers.

## II. DEVELOPMENT AND ACTIVITY OF THE COMMITTEE

The Astronomy Mini-Study Committee met at Woods Hole for the first time on June 13-15, 1974. Attendants at the meeting were:

Dr. Leo Goldberg (Chairman), Astronomer and Director of Kitt Peak National Observatory.

Dr. Alexander Dalgarno, Professor of Astronomy and Chairman of the Department of Astronomy, Harvard University.

Dr. Frank Drake, Professor of Astronomy, Cornell University, and Director of the National Astronomy and Ionosphere Center.

Dr. Robert Fleischer, Head, Astronomy Section, National Science Foundation.

Dr. Ivan King, Professor of Astronomy, University of California, Berkeley.

Dr. Robert Kraft, Professor of Astronomy, University of California, Santa Cruz, and President, American Astronomical Society.

Dr. Beverly Lynds, Astronomer and Assistant to the Director, Kitt Peak National Observatory.

Dr. Peter Meyer, Professor of Physics, University of Chicago.

Ms. Beverly Porter, Deputy Director, Manpower Division, American Institute of Physics.

Dr. Malvin Ruderman, Professor of Physics, Columbia University.

Dr. Henry Smith, Deputy Associate Administrator - Science, Office of Space Science, National Aeronautics and Space Administration.

At this initial meeting, preliminary statistics in the astronomical population with respect to total numbers, age distribution, field of Ph.D., employment and growth were discussed and several more detailed analyses were requested of the 1973 AIP survey. The Committee then reviewed the current and possible future federal funding for astronomy. General discussions were held on the research potential of the field and on possible new modes of employment of astronomers. The Committee agreed to discuss all issues with their colleagues and to reconvene in the fall in order to produce a final report.

Detailed minutes of the Woods Hole meeting were prepared and distributed to the Committee members. In addition, Dr. Goldberg sent copies of the minutes to astronomers at about 70 different universities and research institutions and asked them to discuss the issues with their colleagues and advise him of their suggestions and opinions. Responses were received from 45 scientists, many of whom spoke for an entire department.

The comments from these respondees plus notes from a Tucson meeting of seven additional astronomers and administrators (from KPNO, NRAO, SAO, and the University of Arizona) were compiled and categorized by subject matter and the resulting report was mailed to all members of the mini-study prior to its fall meeting.

A second meeting of the mini-study was held at the National Academy of Sciences on September 27-28 and was attended by the original steering group plus five additional participants:

Dr. Donald Backer, Goddard Space Flight Center

Dr. Richard Berendzen, Dean of College of Arts and Sciences, American University

Dr. Kate Brooks, Los Medanos Community College

Dr. Martin Green, Advisory Engineer, Electro-Optical Department, Westinghouse Electric Corporation

Dr. Joseph Schwartz, Center for Astrophysics, Harvard & Smithsonian Obs.

Other guests included Mr. Charles Reed, Executive Director, Assembly of Mathematical and Physical Sciences of the National Research Council; and Dr. Jack Sanderson, Head, Office of Budget, Programming and Planning Analysis of the National Science Foundation (now Deputy Director, Office of Planning and Resources Management).

Porter had provided the detailed statistical data requested by the Committee.

The Committee spent the first day discussing the main issues identified at the Woods Hole meeting and other points raised by their colleagues, by industry and by university administrations. On the second day the Committee reached decisions on the nature of the final report and discussed its conclusions and recommendations. This report is the resulting document.

III. COMMITTEE REPORT

A. Graduate Training

According to Table III, there are about 50 Ph.D.'s employed in astronomy over the age of 60 and more than 500 under the age of 35. This can be generalized to the statement that there are ten times as many astronomers entering the field as are leaving it.

If it is assumed that the present population of Ph.D. astronomers in the U.S. is 1800 and that the average career span for each is 40 years, then an employment rate of 45 new Ph.D. astronomers per year would achieve an equilibrium rate if the age distribution were uniform. It is clear that the number of new persons seeking employment exceeds this steady-state value by at least a factor of 4 and even then the equilibrium will not be achieved until the end of the century because of the skewness of the age distribution.

If the career span were reduced through early retirement, then a higher employment rate could be accommodated. Many universities are now exploring this possibility and if it proves viable for the future it will help to alleviate the problem. Very few positions would become available immediately, but it is hoped that the promise of future tenured positions becoming available will enable universities to argue for an extension of support for their junior staff for about the next decade.

*Although the employment opportunities in astronomy may increase it is clear that the rate of production of Ph.D.'s seeking employment in astronomy must be reduced. It is the responsibility of every university department which produces Ph.D.'s with specializations in astronomy and astrophysics to assist in achieving this reduction. The Committee recommends that university departments take the following steps: (1) to inform potential students of the current employment problem in astronomy and to provide assistance to the potential student in evaluating his or her achievement capability, (2) to screen carefully the students both prior to admittance to the graduate program and during the early years of graduate work, and (3) to provide a program which will enable each student to achieve adequate mobility with respect to employment opportunities.*

*The Committee recommends that the American Astronomical Society assume the responsibility of overseeing the distribution of a standard*

*letter to all Ph.D. granting institutions having specializations in astronomy and/or astrophysics and of urging these institutions to adopt this letter and to mail it to every student seeking admission to graduate work. An example of the type of letter envisaged by the Committee follows:*

Dear Student:

You should now be giving serious thought to the career you expect to have after completing your graduate work. Astronomy is an intellectually exciting field in which major advances are being made, covering a broad spectrum of the physical sciences.

Traditionally, the most desirable positions for a young astronomer have been those at large universities or major observatories where one could devote a substantial fraction of time to research. However, the increased numbers of graduate students in the physical sciences, the overall decreased enrollment at the undergraduate levels, and the decreased funds available for research have combined to make the prospect of obtaining such positions increasingly difficult. Opportunities will be available, of course, but the ratio of candidates to available positions at current rates of Ph.D. production is projected to be more than 4 to 1.

You should now seriously consider whether your interest in the field is so great that you wish to devote five more years of hard study to astronomy, knowing that at the end of those years the main job openings will probably be in fields entirely different from astronomy.

With the subject matter of the physical sciences changing so rapidly, it is not uncommon for a person who acquires knowledge and research experience in one field to change later to an allied one. The positions which will be available to you will be filled on a highly competitive basis, and you must be very honest with yourself in assessing your chances of success not only for completion of the Ph.D. but also in the competition

for employment. We will do everything possible to advise you carefully as to your chances for future success in both graduate school and your intended career.

As an initial step in this procedure, we can give you a rough indication of a typical student who might be admitted to a graduate program. For undergraduate grades, the student had more A's than B's at a good institution. The student scored well on both the verbal and the quantitative parts of the GRE and had very good recommendations from professors. None of these is an absolute criterion, because no test has been devised yet to measure such intangibles as originality, but they may provide a helpful guide in allowing you to carry out a self-evaluation of your potential.

Very sincerely yours,

Departments of astronomy differ in the manner in which the students are screened. Several of the leading departments have already drastically cut down the number of students they admit to their graduate program. Other departments have admitted many but selectively "weed out" a large fraction of them during their first few years of graduate studies. Some departments depend heavily on graduate student assistants in discharging the teaching and research responsibilities of the department, and therefore encourage large graduate enrollments.

*The Committee recommends that faculty members assume more undergraduate teaching responsibilities and that post-doctoral fellows be considered for positions as research assistants to fill the need created by smaller graduate enrollments.*

The employment crisis in astronomy must be faced not only by the young people but by university departments as well. The ever-increasing number of Ph.D. producing departments is a cause of some concern although it also reflects the enormous enthusiasm the academic world now has for the science.

*The Committee recommends that all existing astronomy departments and all embryonic ones achieve close cooperation in the organization*

*of curricula between physics and astronomy specializations. Furthermore, it is recommended that astronomy departments, old and new, make certain that they are not overemphasizing graduate courses at the expense of imaginative and attractive undergraduate offerings.*

The result of these recommendations will undoubtedly mean that senior faculty members will have to teach more and that departments will have to curtail their graduate population but if both actions are carried out they should balance the criteria for university support for the department. This contribution by senior members of the profession will assist in allowing departments to continue to maintain a junior staff as long as the undergraduate popularity of the field exists.

It is also the responsibility of each graduate department to make sure that its students receive a training broad enough to make them competitive with other candidates for the job market. At present, having a Ph.D. in astronomy rather than physics puts the applicant at a disadvantage when competing for employment in industry and in many four year colleges. This disadvantage may be caused by the incorrect "image" an astronomer has in the eyes of industrial recruitment officers and university officials; however, some astronomers are very poorly equipped to handle problems outside a narrow specialty because of a lack in breadth in their training. It is up to the entire community of astronomers to correct the image that astronomers are able only to look through a telescope and ponder the riddles of the universe. There is also some real evidence that many of our young Ph.D.'s are indeed much too overspecialized and have not received sufficient diversification in their graduate work, especially with respect to physics courses. A properly trained astronomer should be fully as capable of teaching the undergraduate physics and astronomy courses in a college as a physicist is; and if the astronomer has instrumental talents he should be a valuable asset to modern technology as practiced not only in astronomy but also in industry.

*The Committee recommends that all departments offering graduate studies in astronomy review their graduate curriculum and their attitudes toward employment opportunities in the light of the current*

*situation in astronomy. To become employable, graduate students must have opportunities to gain experience in teaching, in computer applications, electronics, or in special fields of a related science. They will need the understanding and support of their professors as they prepare themselves for such diversified careers.*

On the basis of the data presented in this section, it is clear that the government has invested a substantial sum in astronomical facilities and research. It is regrettable that federal support for the physical sciences is decreasing and that so popular and vigorous a field as astrophysics must realistically project at best essentially level funding in future years.

*One area of research that has suffered from cutbacks in federal support is the analysis of data from space missions. It is imperative to achieve the optimum balance between the support of major space missions on the one hand, and the support of the specialists who obtain, analyze and interpret the wealth of new astronomical data produced by such programs on the other. The young space scientists who must be counted on to design the experiments to be flown in the shuttle are actually being forced out of the field because they cannot find employment.*

*The Committee suggests that NASA make a careful study of the need for data analyses in the astronomy program.*

B. Employment

1. Industry

One of the most striking differences in the employment patterns of astronomers and physicists is the under-representation by astronomers in industry (6% compared to 22%). Furthermore, most of the Ph.D. astronomers employed by industry are working for companies which are heavily engaged in the space programs and are essentially funded by NASA. A sampling of the opinions of certain companies has uncovered the general belief that astronomers are star-gazers who enjoy contemplating the mysteries of the universe and are not suited for the more mundane and practical hard-headed matters that industry faces. The companies also thought that students of astronomy ought to be trained in skills that are needed, such as computer applications, electronics, instrumentation, etc. If astronomers are to compete for industrial positions, then greater attention must be given to assuring that they have the skills industry needs. Astronomy has a very exciting field of activities and a very broad and diverse range. If this fact is coupled into some specific project training then a specialist would emerge who not only could contribute significantly to astronomy but also to industry.

On the basis of a sampling of attitudes on hiring astronomers by one high-technology corporation, the following points were made:

(1) The Ph.D. astronomer is seen primarily in this context as an individual with a research training that should give him a sound analytical ability and a general scientific training. He is regarded as having leadership potential.

(2) An undergraduate training in physics or electrical engineering is regarded as essential to his general background. Both theoretical astronomers and those with an undergraduate training in astronomy are considered to be too specialized.

(3) At the present time the general background of the Ph.D. astronomer is more attractive to a development group in a manufacturing division than it is to a research laboratory. The need to understand a customer's requirements for a sophisticated component or to analyze a total system calls for a man with a general physics background.

(4) Hiring Ph.D.'s in a manufacturing division seems to present no "psychological" problems.

(5) Practical experience with building instruments and getting one's hand "dirty" are regarded as desirable traits.

(6) The job candidate must try to relate his past experience to the needs of his potential employer. He must understand that he will become an engineer, not an astronomer, and can probably advance by providing leadership to a group of "specialists" (for example, he should demonstrate that "he can get the job done").

(7) An M.S. degree or equivalent training in Computer Science, Optics, Nuclear Physics, Electronics, or Solid State Physics is an advantage.

(8) The candidate should seek out high technology industries.

Astronomers could gain more visibility in industry by actively participating in the NSF Faculty Research Participation Program of the NSF Division of Higher Education in Science. This program, in which academic faculty are encouraged to participate in research in an industrial type of setting, is planned to assist in adding another dimension to the instruction of students of science in colleges and universities. If astronomers participated in this program they could overcome the image that an astronomer is not employable in industry, they would gain an insight into the kind of advice they should

give the students in preparing them for industrial positions, and they could establish contracts in industrial areas.

There would also be some advantage to the program being expanded to include those persons in pure research positions and particularly those holding post-doctoral research positions. This would be one mechanism of assisting young astrophysicists in broadening their field of expertise so that alternative careers might be developed.

2. Teaching

The enthusiasm for astronomy evidenced by the ever-increasing graduate enrollment and Ph.D. production is also reflected in the interest shown by undergraduate students and by the public in general. All physical scientists and astronomers in particular have now an opportunity to assist in developing a more scientifically aware society and to achieve large gains in the scientific literacy of the nation. On the practical side, increasing enrollment in undergraduate astronomy courses brings financial support to a department and enables it to support its faculty.

*The Committee recommends that the American Astronomical Society take the lead in a concentrated drive to expand undergraduate programs in astronomy and to seek out and encourage all junior colleges, colleges and universities not now staffed with an astronomer as a faculty member to introduce this exciting program into their curricula.*

Table XIV, provided by the AIP, summarizes the involvement of trained astronomers and others teaching astronomy at the various educational levels.

*TABLE XIV*

*NUMBER OF ASTRONOMY TRAINED AND NON-ASTRONOMY TRAINED INSTRUCTORS IN UNIVERSITIES, COLLEGES, AND SCHOOLS WHO TEACH ASTRONOMY-ORIENTED COURSES*

| | University Ph.D. Depts. | | University M.A. Depts. | | Col. & Univ. B.A. Depts. | | Jr. Colleges | | Sec. Schools | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # | % | # | % | # | % | # | % | # | % |
| *Astronomy-trained* | 259 | (76) | 30 | (54) | 51 | (39) | 18 | (43) | 4 | (16) |
| *Non-astronomy-trained* | 80 | (24) | 26 | (46) | 80 | (61) | 24++ | (57) | 21++ | (84) |

*++ 2/3 of these people hold science teaching degrees below the Ph.D. level.*

Data from the 1973 AIP Survey.

The figures for non-astronomers should be considered lower limits because scientists only peripherally tapped in the AIP survey may be teaching astronomy.

Students are not included in the figures of Table XIV. Sixty students teach some astronomy on assistantships in Ph.D. departments; 10 students teach at the other educational levels. Clearly at the university level the astronomy-trained individual holds most of the teaching positions, particularly at the Ph.D.-producing departments. But at four-year colleges and lower the situation is quite different; non-astronomers dominate the situation.

The AIP has also provided listings of four-year colleges offering introductory courses in astronomy; 401 are listed. On the basis of Table XIV, we infer that very few of the colleges have astronomers teaching these courses. An additional list of four-year colleges offering no astronomy was provided; 64 of these latter institutions have faculties greater than 100 and may be good candidates for program enrichment in the field of astronomy.

The AIP also lists 34 two-year colleges offering associate degrees in astronomy and 359 two-year colleges not offering astronomy courses in 1974-1975.

As an example of the contacts needed, a recent Sigma Xi lecturer, who is an astronomer, visited two universities with enrollments of 9000 each. Both universities offer elementary astronomy courses with the teaching being done by a physics department professor. In both universities, the administrators indicated that they would like to hire an astronomer and if someone would come forward it probably could be arranged. But it appeared necessary for the initiative to come from the outside. The AAS, under its Shapley Lectureship Program, has one mechanism which would enable senior astronomers to encourage such universities to strengthen their astronomical offerings.

The interest shown by undergraduate students is frequently generated in elementary and secondary schools, where astronomical

subjects are being introduced more and more in the general science and physics programs.

*The Committee recommends that astronomy department heads of all state universities make an effort to suggest to their state legislatures that an astronomy course be incorporated as a science credit for all new and continuing education students and teachers.*

The technology of teaching undergraduate science courses is developing in an accelerated way and many innovative aids are available which lighten the burden of the teacher. An effort should be made by all educators to use these state-of-the-art techniques in order to make their courses more interesting and to give the lecturer more flexibility in the allocation of his time.

If, with a major effort on the part of the astronomical community, a number of new teaching positions are opened up for young astronomers, then the astronomical community should also look for new ways to enable these talented young people to continue their research careers. Heavy teaching loads and relative isolation from colleagues will make research difficult to carry out during the academic year. It is possible, however, for such persons to join an active research group during the summer recess. Modest programs at the National Centers are already underway, and the major university centers of astronomical research might also develop such summer institutes perhaps with the support of federal funds from HEW and NSF education funds. The recent technological advances in observational astronomy give promise of providing such a wealth of data that major inroads in the fundamental problems of astrophysics can be made with a team effort of data reduction and analysis. Such teams could well be centered at one of the major universities or observatories and could easily accept young Ph.D. astronomers during the summer as collaborators. Thus it would be advantageous to the science and to the educational field to



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have such efforts underway. A scientist active in research is usually the most valuable and inspiring science teacher.

The NSF has recently announced that opportunities are available for faculty members of smaller institutions to remain active in organized and basic research by participating in research supported by NSF at large active departments of a nearby university.

In recommending the enrichment of college programs by the introduction of astronomy in the curriculum, the Committee realizes that the skills and expertise of mature astronomy teachers are critically needed. The first step in developing new astronomy programs in colleges now having none would consist of the placement of such an experienced and knowledgeable astronomer in the college for several years in order to get the program established. It would then be easier for a young astronomer to join the program. Perhaps it would be possible to find support from private foundations or from federal sources to introduce a distinguished professor program whereby a person within a few years of retirement would be willing to leave his home institution in order to contribute to the enrichment of another four-year college. The college would benefit, and the home institution could then employ a young person in place of the senior professor. The funds needed would be the salary and moving expenses of the senior professor for the few years prior to retirement. A coordinated effort would be needed in finding funds, interested senior astronomers, and interested colleges.

The preceding suggestion is an alternative to the possibility of early retirement which is now frequently discussed in academic circles. As indicated by the increasing percentage of tenured astronomers among the leading departments of astronomy, there is some concern that a "generation gap" will develop in such academic departments which cannot expand to hire young people. At present the usual procedure is to maintain the

young population in non-academic positions. For the continued health of the science it is necessary to keep a young and active population of research workers and these young people need some hope that permanent positions will become available to them.

The problem has now become acute in astronomy. Unless additional positions become available, it is inevitable that hundreds of young persons already trained or now being trained in astrophysics will have to leave the field entirely. Immediate efforts should be made to find at least 200 new positions for the young Ph.D. astronomers now in temporary positions. While the effort is underway, it is hoped that employers of these young scientists will attempt to extend the duration of the temporary appointment. At the same time, a reduction in the Ph.D. production rate of persons specializing in astronomy should be begun. These measures will not solve the problem but only alleviate it. The ratio of astronomers under forty years of age to those over 50 years is nearly 6 to 1 and if all of the younger cohort seek permanent employment in the traditional modes, only one in 6 will be successful. The possibility of an unemployment rate of near six hundred percent is indeed staggering!

All of the recommendations in this report require the full cooperation of the astronomy and physics communities and many of the alternatives suggested will require basic changes in outlook of the mature group of astronomers and a real commitment of time on the part of a few influential senior persons in the field. It is hoped that the community will respond to this need.

REFERENCES

(1) *Astronomy and Astrophysics for the 1970's*, Volume 1. (Washington, D.C.: National Academy of Sciences, 1972.)

(2) *Science Indicators 1972*, Report of the National Science Board. (Washington, D.C.: National Science Foundation, 1973.)

(3) Cartter, Allan M., "Faculty Needs and Resources in American Higher Education:, *The Annals of the American Academy of Political and Social Sciences*, Volume 404, November 1972.

(4) Barisch, Sylvia, "A Parting Look at the National Register", *Physics Today*, October 1971.

(5) Porter, Beverly F., Barisch, Sylvia F., and Sears, Raymond W., "A First Look at the 1973 Register", *Physics Today*, April 1974.

(6) *Astronomy and Astrophysics for the 1970's*, Volume 2. (Washington, D. C.: National Academy of Sciences, 1973.)

(7) Bok, Bart J. and Goldsmith, Donald W., "Present Employment Trends in Astronomy", *Mercury*, July/August 1973.



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